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AERODYNAMIC CHARACTERISTICS OF A FULL-SCALE F-101 EJECTION SEAT WITH AN ANTHROPOMORPHIC DUMMY AT FREE-STREAM MACH NUMBERS FROM 0.2 TO 0.8

Lawrence L. Galigher

ARO, Inc.

March 1972

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FOREWORD

The test reported herein was sponsored by the San Antonio Air Material Area (SAAMA), Air Force Systems Command (AFSC), under Program Element 921A.

The results of the test were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract F40600-72-C-0003. The test was conducted from January 27 through 28, 1972, under ARO Project No. PB0234. The manuscript was submitted for publication on February 18, 1972.

This technical report has been reviewed and is approved.

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ABSTRACT

A test was conducted in the Propulsion Wind Tunnel, Transonic (16T), of the Propulsion Wind Tunnel Facility to determine the aerodynamic characteristics of a full-scale F-101 ejection seat occupied by an anthropomorphic dummy at free-stream Mach numbers of 0.2, 0.4, 0.6, and 0.8. Angle of attack was varied from -45 to +90 deg, and angle of yaw was varied from 0 to +45 deg, depending on the angle of attack. Reynolds number effects on the model aerodynamic characteristics at Mach numbers of 0.4, 0.6, and 0.8 were within the precision of the data through the Reynolds number range investigated. For the moment reference center selected, the model was longitudinally stable through the angle-of-attack range from -45 to approximately +20 deg at Mach number 0.2 and to approximately +10 deg at Mach number 0.8. The model was directionally and laterally unstable near zero angle of yaw at Mach numbers from 0.2 to 0.8.

CONTENTS

APPENDIX
ILLUSTRATIONS

NOMENCLATURE

A	Model frontal projected area, 8.25 ft^2
A_1	Model reference area based on half-scale model, 6.92 ft^2
C_A	Axial-force coefficient, positive downstream, $F_A/q_\infty A$
C_{A1}	Axial-force coefficient relative to model axis system for the half-scale model, positive downstream, $[C_A \cos\theta - C_N \sin\theta](A/A_1)$
C_ℓ	Rolling-moment coefficient, positive clockwise looking upstream, $M_\ell/q_\infty A\ell$
C_m	Pitching-moment coefficient, positive nose up, $M_m/q_\infty A\ell$
C_{m1}	Pitching-moment coefficient relative to the moment reference center for the half-scale model, positive nose up, $[\ell C_m - X_T C_N + Z_T C_A](A/A_1\ell_1)$
C_N	Normal-force coefficient, positive up, $F_N/q_\infty A$
C_{N1}	Normal-force coefficient relative to model axis system for the half-scale model, positive up, $[C_N \cos\theta + C_A \sin\theta](A/A_1)$
C_n	Yawing-moment coefficient, positive nose right, $M_n/q_\infty A\ell$
C_Y	Side-force coefficient, positive to the right looking upstream, $F_Y/q_\infty A$
F_A	Model axial force, positive downstream, lbf
F_N	Model normal force, positive up, lbf
F_Y	Model side force, positive to the right looking upstream, lbf
ℓ	Model reference length, $\sqrt{4A/\pi}$, 3.241 ft

ℓ_1 — Model reference length based on half-scale model, 4.0 ft

M_ℓ — Model rolling moment, positive clockwise looking upstream, ft-lbf

M_m — Model pitching moment, positive nose up, ft-lbf

M_n — Model yawing moment, positive nose right, ft-lbf

M_∞ — Free-stream Mach number

q_∞ — Free-stream dynamic pressure, psf

Re,ℓ — Free-stream Reynolds number per foot, 1/ft

V_∞ — Free-stream velocity, ft/sec

X_T — Location of half-scale moment reference center relative to the full-scale moment reference center as measured in the full-scale model axis system, positive direction forward of full-scale moment reference center, -0.3612 ft

Z_T — Location of half-scale moment reference center relative to the full-scale moment reference center as measured in the full-scale model axis system, positive direction below the full-scale moment reference center, -0.0025 ft

α — Model angle of attack, positive nose up, deg

α_1 — Model angle of attack relative to model axis system for the half-scale model, positive nose up, $\alpha + \theta$, deg

θ — Rotation of half-scale model axis system relative to the full-scale model axis system, positive nose up, 9.25 deg

ψ — Model yaw angle, positive nose right, deg

SECTION I
INTRODUCTION

The objective of this test program was to determine the aerodynamic characteristics of a full-scale, F-101 ejection seat occupied by an anthropomorphic dummy at Mach numbers from 0.2 to 0.8. Angle of attack was varied from -45 to +90 deg; and angle of yaw was varied from 0 to +45 deg, depending on the angle of attack.

SECTION II
APPARATUS

2.1 TEST FACILITY

Tunnel 16T is a continuous-flow, closed-circuit wind tunnel capable of operating within a Mach number range from 0.2 to 1.6. The test section is 16 by 16 ft in cross section and 40 ft in length. The tunnel can be operated within a stagnation pressure range from 120 to 4,000 psfa depending on the Mach number. Stagnation temperature can be varied from approximately 80 to a maximum of 160°F, and the specific humidity of the air is controlled by removing tunnel air and supplying conditioned makeup air from an atmospheric dryer. A more complete description of the Tunnel 16T and its operating characteristics is contained in Ref. 1.

2.2 TEST ARTICLE

The test article was a full-scale F-101 ejection seat occupied by a 95-percentile anthropomorphic dummy dressed in flight boots and helmet and wearing a backpack BA-18 parachute. The seat is a catapult-powered, open-type upward ejection seat; and for this test program, the back of the seat was modified for force-balance attachment to a sting support system. A flange-face, model-to-sting attachment provided the capability to pitch the test article through an angle-of-attack range from -45 to +90 deg. Yaw angle capability was achieved by a combination of sting pitch and roll angle. A sketch showing the sting support system and the location of the test article in the wind tunnel test section is shown in Fig. 1 (Appendix). Also shown in Fig. 1 are the two flange-face attachments used during this test program to provide a model pitch capability from -45 to +90 deg. Wind tunnel installation photographs of the test article are shown in Fig. 2, and the major dimensions of the ejection seat are shown in Fig. 3.

2.3 INSTRUMENTATION

A six-component, strain-gage balance was used to measure model forces and moments. The balance data were recorded on the facility automatic digital data system, and the balance outputs were continuously recorded on a direct-writing oscillograph for monitoring model dynamics.

SECTION III
PROCEDURE

3.1 TEST CONDITIONS

The model was tested at free-stream Mach numbers of 0.2, 0.4, 0.6, and 0.8 through an angle-of-attack range from -45 to +90 deg. Yaw angle was varied from 0 to +45 deg depending on the angle of attack. The data for Mach number 0.2 were obtained at simulated sea-level test conditions. The data for Mach numbers 0.4, 0.6, and 0.8 were obtained at a nominal free-stream dynamic pressure of 160 psf. The effect of Reynolds number on model aerodynamic characteristics was also investigated at Mach numbers of 0.4, 0.6, and 0.8.

3.2 DATA REDUCTION

The balance force and moment data were corrected for weight tares and reduced to coefficient form in the body axis system as shown in Fig. 4. The moment coefficients were referred to the moment reference center also shown in Fig. 4. The force and moment coefficients were based on a reference area equal to the model projected frontal area and a reference length equal to the diameter of a circle whose area is equal to the model projected frontal area.

3.3 PRECISION OF MEASUREMENTS

The uncertainty of free-stream Mach number in Tunnel 16T, as estimated from tunnel calibrations, is ±0.003 at subsonic Mach numbers. The uncertainties of the tunnel parameters were combined with the uncertainties of the balance measurements to estimate the precision of the model parameters as follow:

Parameter	Precision
α	±0.1 deg
ψ	±0.1 deg
C_A	±0.10
C_N	±0.008
C_Y	±0.013
C_ℓ	±0.007
C_m	±0.010
C_n	±0.008

SECTION IV
RESULTS AND DISCUSSION

4.1 REYNOLDS NUMBER EFFECT

Reynolds number effects were investigated at free-stream Mach numbers of 0.4, 0.6, and 0.8. The data presented in Figs. 5 and 6 show that Reynolds number effects were

within the precision of the data over the range of Reynolds numbers investigated at each Mach number.

4.2 MODEL AERODYNAMIC CHARACTERISTICS

The variation of the model force and moment coefficients with angle of attack and yaw are presented in Figs. 7 and 8, respectively. The data presented in Fig. 7 in the angle-of-attack range from -5 to +40 deg were obtained from tests with each of the two flange-face attachment arrangements (see Fig. 1) used during this test program. The longitudinal, static stability characteristics of the model can be interpreted from the slopes of the pitching-moment and normal-force coefficient with angle of attack. For the moment reference center selected, the data presented in Fig. 7 indicate that the model was longitudinally stable in the angle-of-attack range from -45 to approximately +20 deg at M_∞ = 0.2 and to approximately +10 deg at M_∞ = 0.8. However, the model trim angle was approximately -35 deg in the Mach number range from 0.2 to 0.8. The directional, static stability characteristics can be obtained in a similar manner from the yawing-moment and side-force coefficient data presented in Fig. 8. These data indicate that, for zero angle of attack, the model was directionally unstable at angles of yaw less than approximately 30 deg at M_∞ = 0.2 and approximately 15 deg at M_∞ = 0.8. For angles of yaw greater than 30 deg at M_∞ = 0.2 and 15 deg at M_∞ = 0.8, the model exhibited neutral, directional stability. In general, directional instability increased at the positive angles of attack and decreased at the negative angles of attack. The lateral stability characteristics can be interpreted from the slope of the rolling-moment coefficient with angle of yaw. These data, as shown in Fig. 8, indicate that, for zero angle of attack, the model was laterally unstable in the Mach number range from 0.2 to 0.8. Lateral instability generally increased at the positive angles of attack and decreased at the negative angles of attack.

4.3 DATA COMPARISON WITH HALF-SCALE MODEL

A data comparison between the full-scale F-101 ejection seat model and a similar half-scale model at M_∞ = 0.6 is shown in Fig. 9. A model installation photograph of the half-scale model is shown in Fig. 10, and the results of the half-scale model test program are documented in Ref. 2. To compare the data, the axial-force and normal-force coefficients for the full-scale model were rotated to the body axis system of the half-scale model, and the pitching-moment coefficient for the full-scale model was transferred to the moment reference center of the half-scale model. As shown in Fig. 9, the normal-force coefficients for the full- and half-scale models agree reasonably well through the angle-of-attack range from -40 to +100 deg. The axial-force and pitching-moment coefficients agree reasonably well through the angle-of-attack range from 0 to +100 and from -40 to 0 deg, respectively. The discontinuity of the axial-force coefficient for the half-scale model at zero angle-of-attack was caused by model-to-sting installation effects; two model-to-sting installation arrangements were required to obtain data through the angle-of-attack range from -40 to +100 deg. It is probable that the disagreement shown for the axial-force and pitching-moment coefficients are predominately the result of model-to-sting installation effects.

SECTION V
CONCLUDING REMARKS

Tests were conducted in Tunnel 16T to determine the aerodynamic characteristics of a full-scale, F-101 ejection seat occupied by an anthropomorphic dummy at Mach numbers from 0.2 to 0.8. Angle of attack was varied from -45 to +90 deg, and angle of yaw was varied from 0 to 45 deg, depending on the angle of attack. A data comparison between the full-scale, F-101 ejection seat model and a similar half-scale model was made at Mach number 0.6. The major results obtained are as follow:

1. Reynolds number effects on the aerodynamic characteristics of the full-scale model at Mach numbers of 0.4, 0.6, and 0.8 were within the precision of the data through the range of Reynolds numbers investigated.

2. For the moment reference center selected, the model was longitudinally stable through the angle-of-attack range from -45 to approximately +20 deg at Mach number 0.2 and to approximately +10 deg at Mach number 0.8. The model was directionally and laterally unstable near zero angle of yaw at Mach numbers from 0.2 to 0.8.

3. The normal-force coefficients for the full- and half-scale models agree reasonably well through the angle-of-attack range from -40 to +100 deg. The axial-force and pitching-moment coefficients agree reasonably well through the angle-of-attack range from 0 to +100 deg and from -40 to 0 deg, respectively.

REFERENCES

1. Test Facilities Handbook (Ninth Edition). "Propulsion Wind Tunnel Facility, Vol. 4." Arnold Engineering Development Center, July 1971.

2. Reichenau, David E. A. "Aerodynamic Characteristics of an Ejection Seat Escape System with Cold Flow Rocket Plume Simulation at Mach Numbers from 0.6 through 1.5." AEDC-TR-69-218 (AD860482), October 1969.

APPENDIX
ILLUSTRATIONS

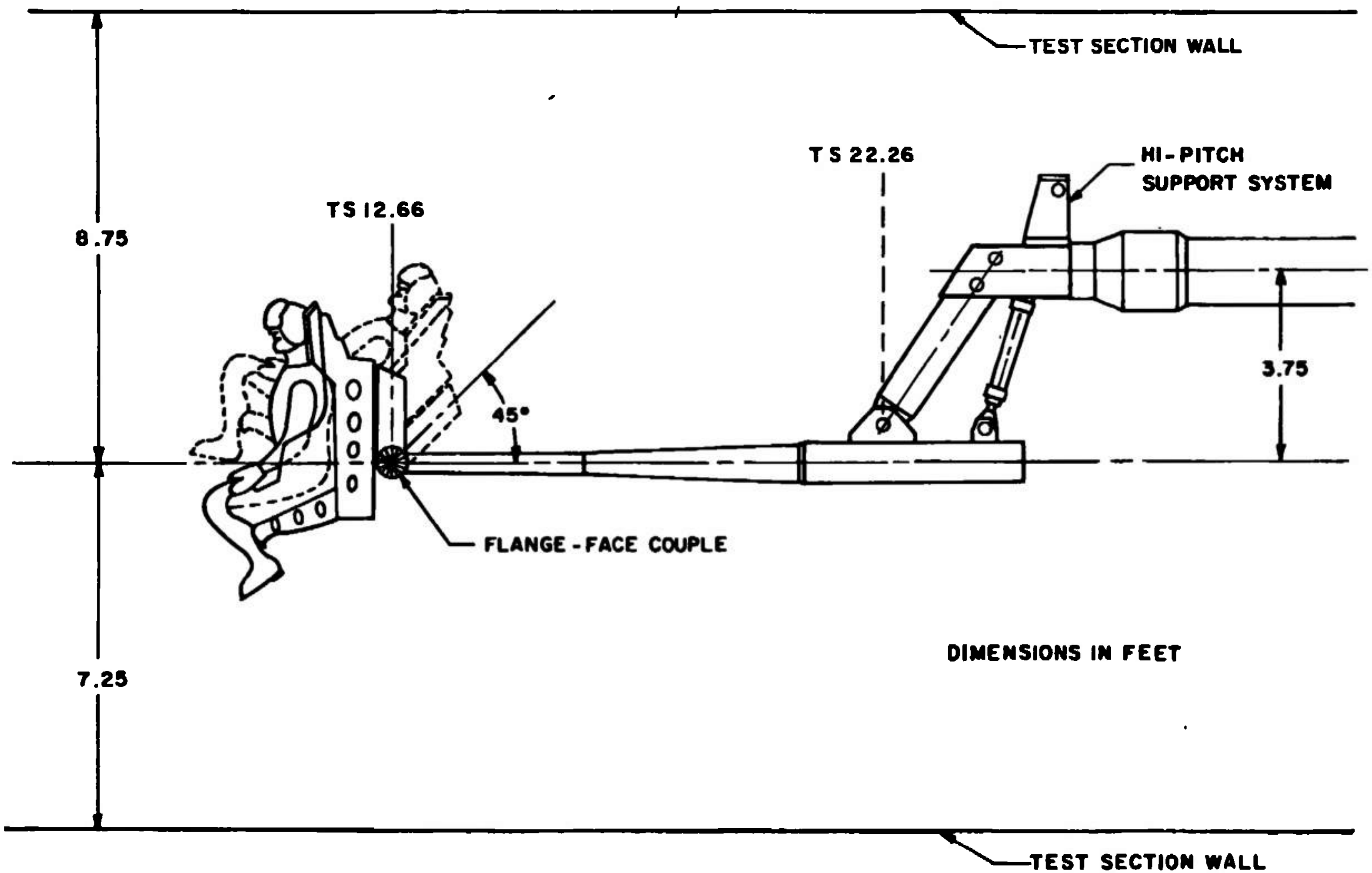
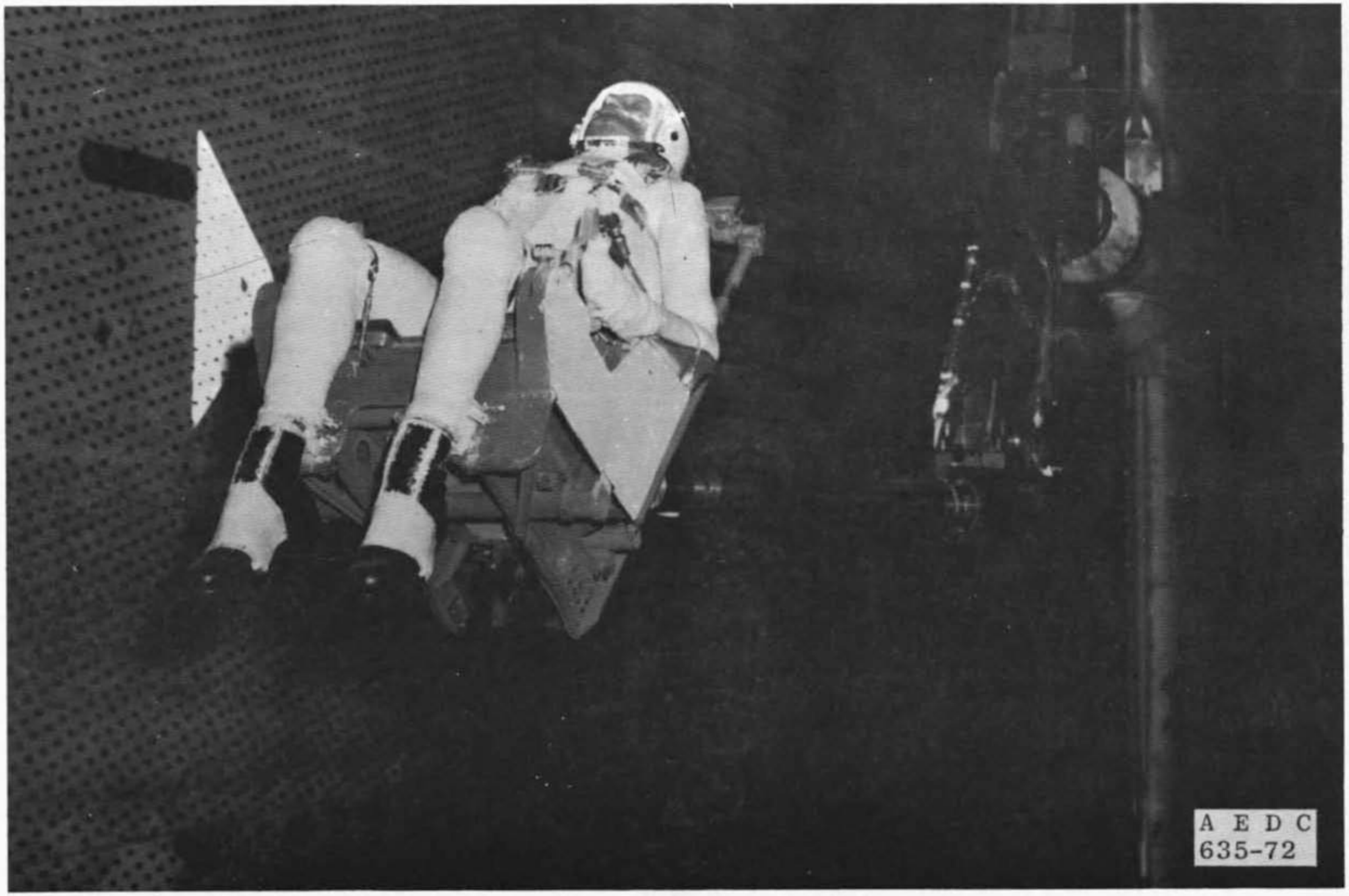
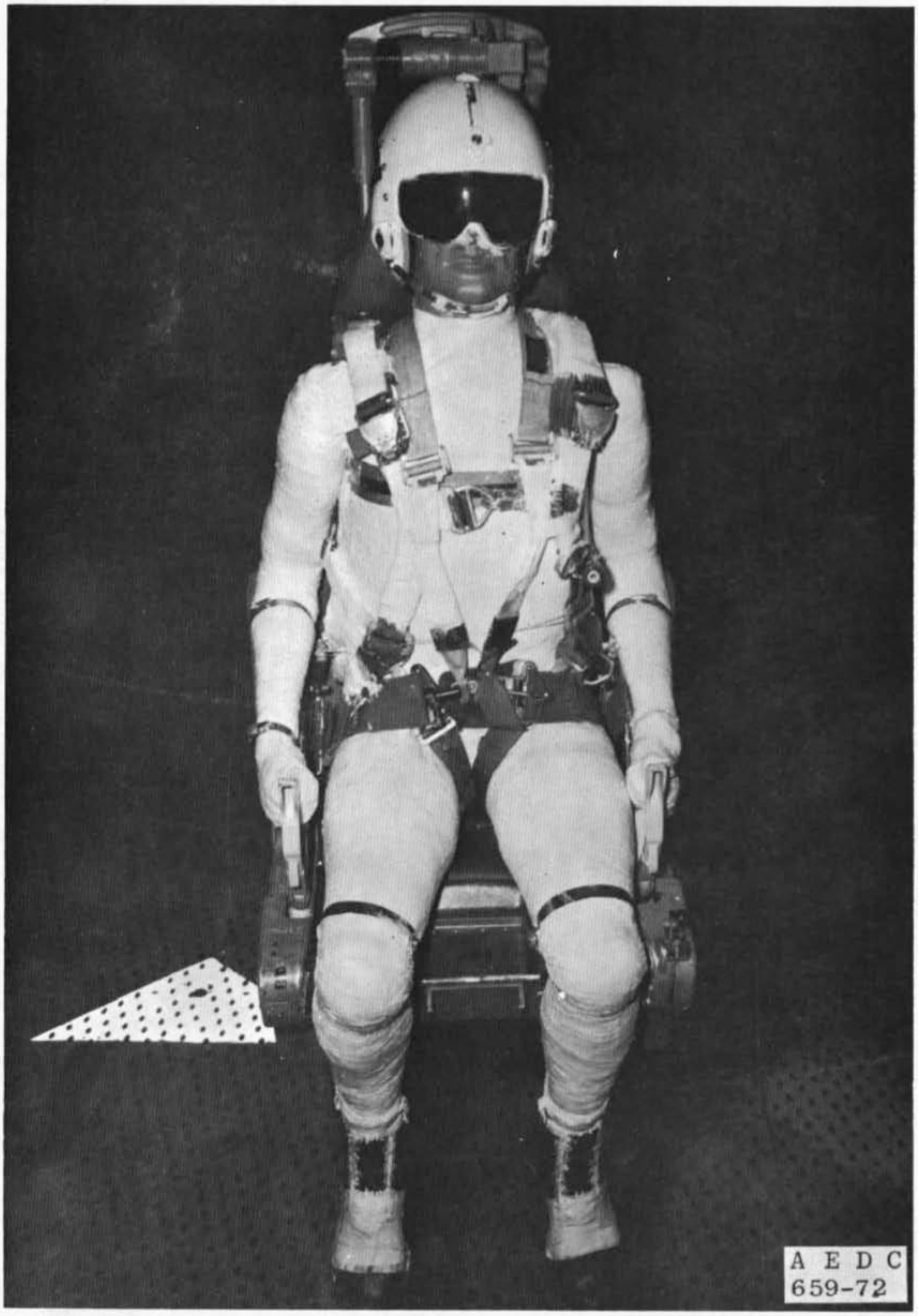


Fig. 1 Model Location in Wind Tunnel Test Section



a. Three-Quarter Front View
Fig. 2 Model Installation Photographs



b. Front View
Fig. 2 Concluded

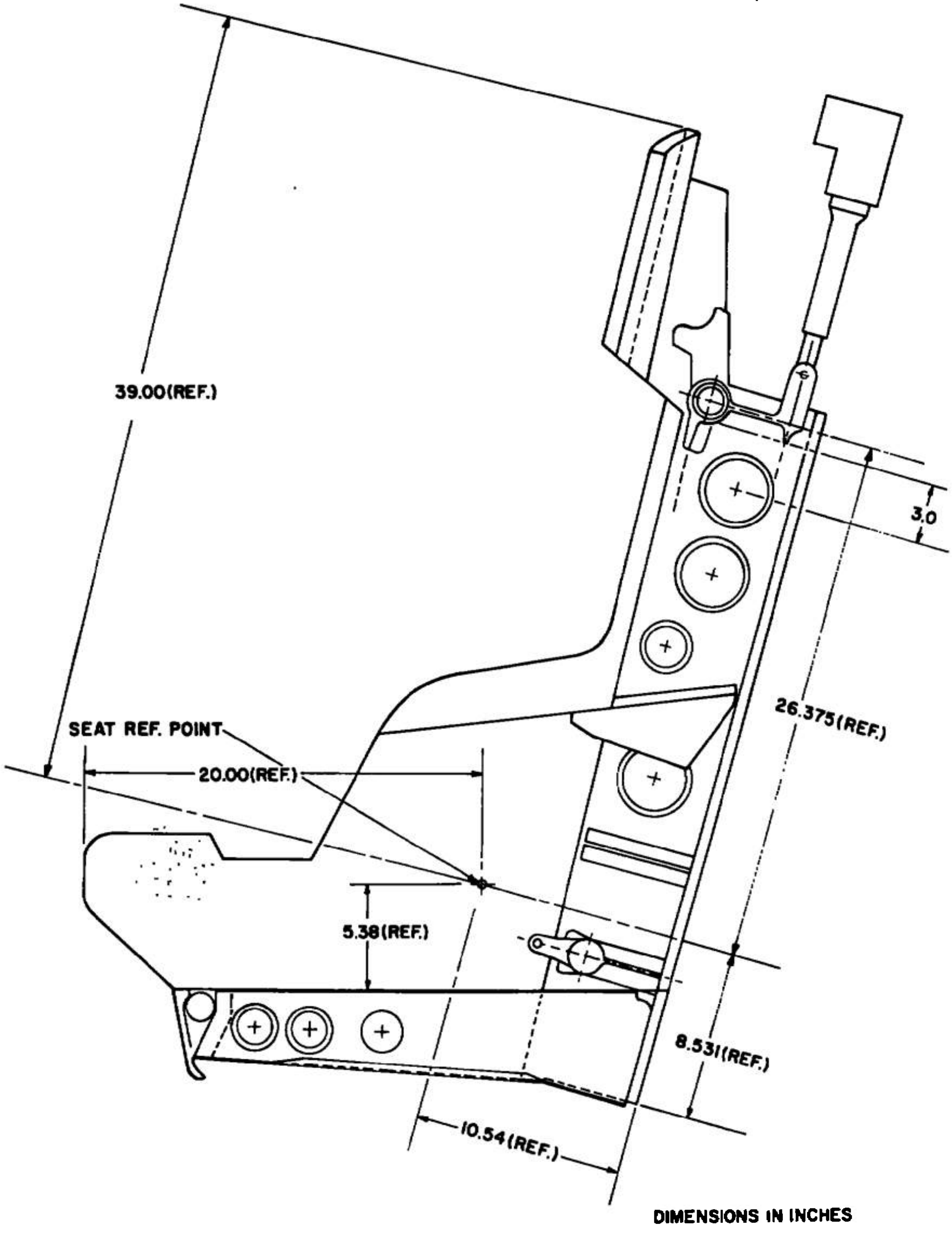


Fig. 3 Dimensional Sketch of F-101 Ejection Seat

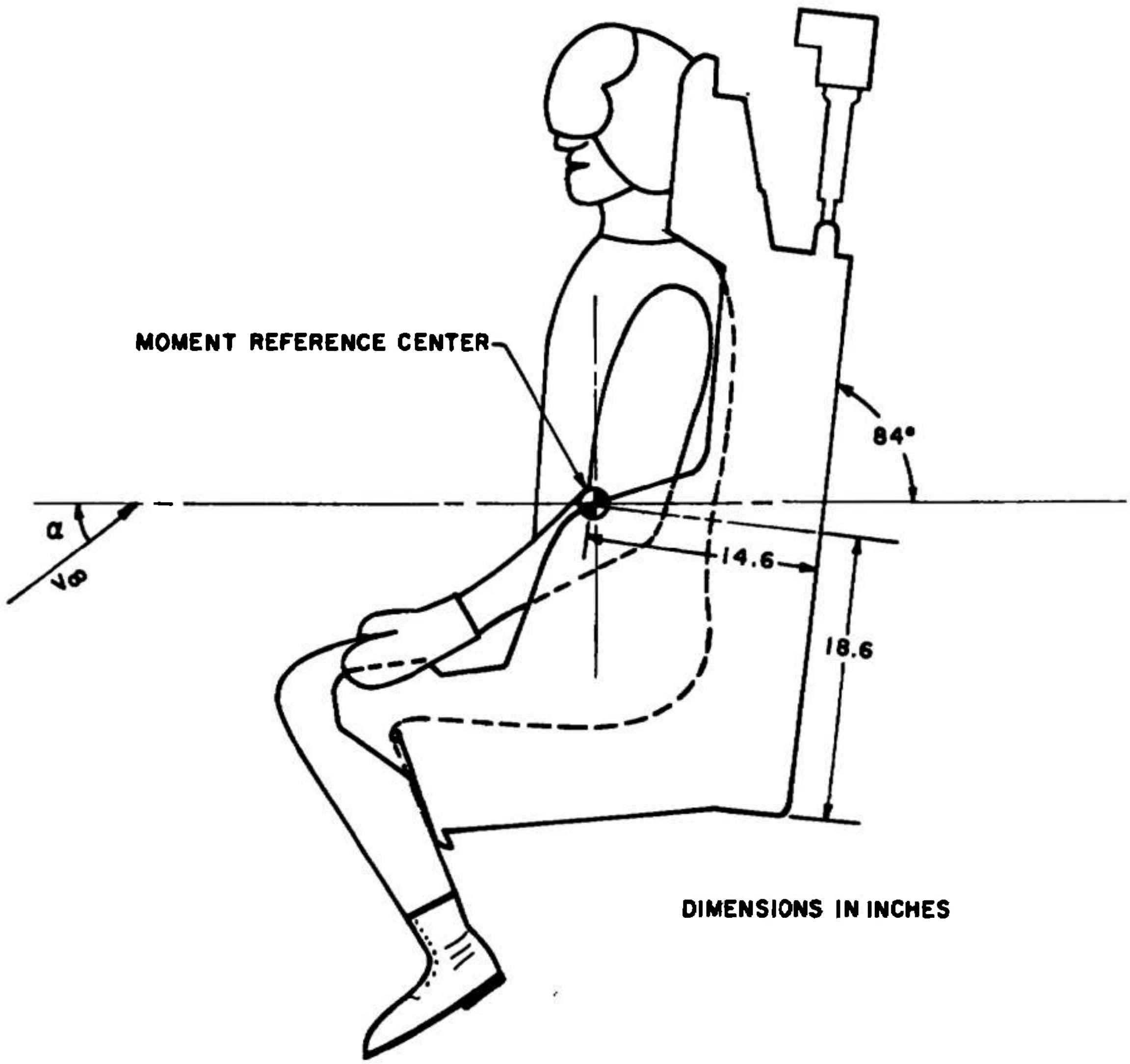
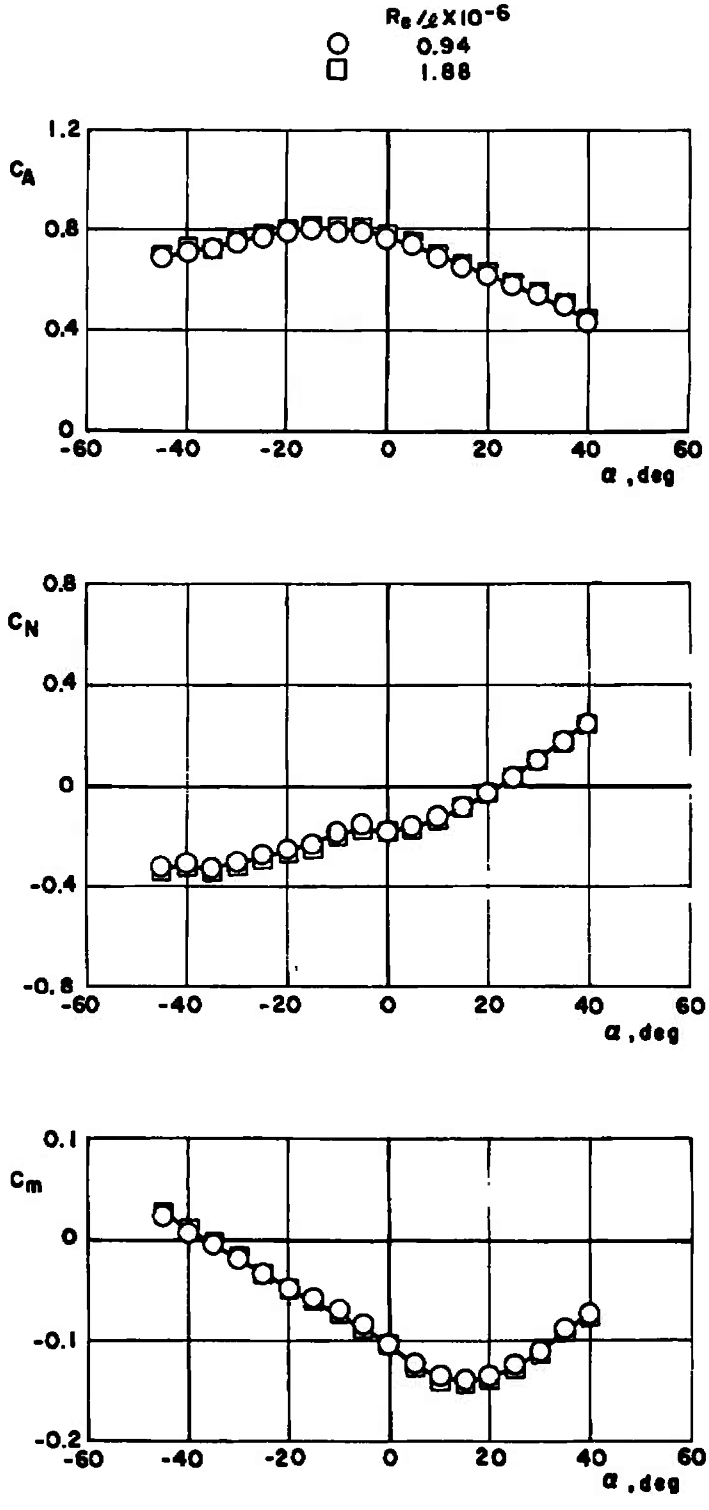
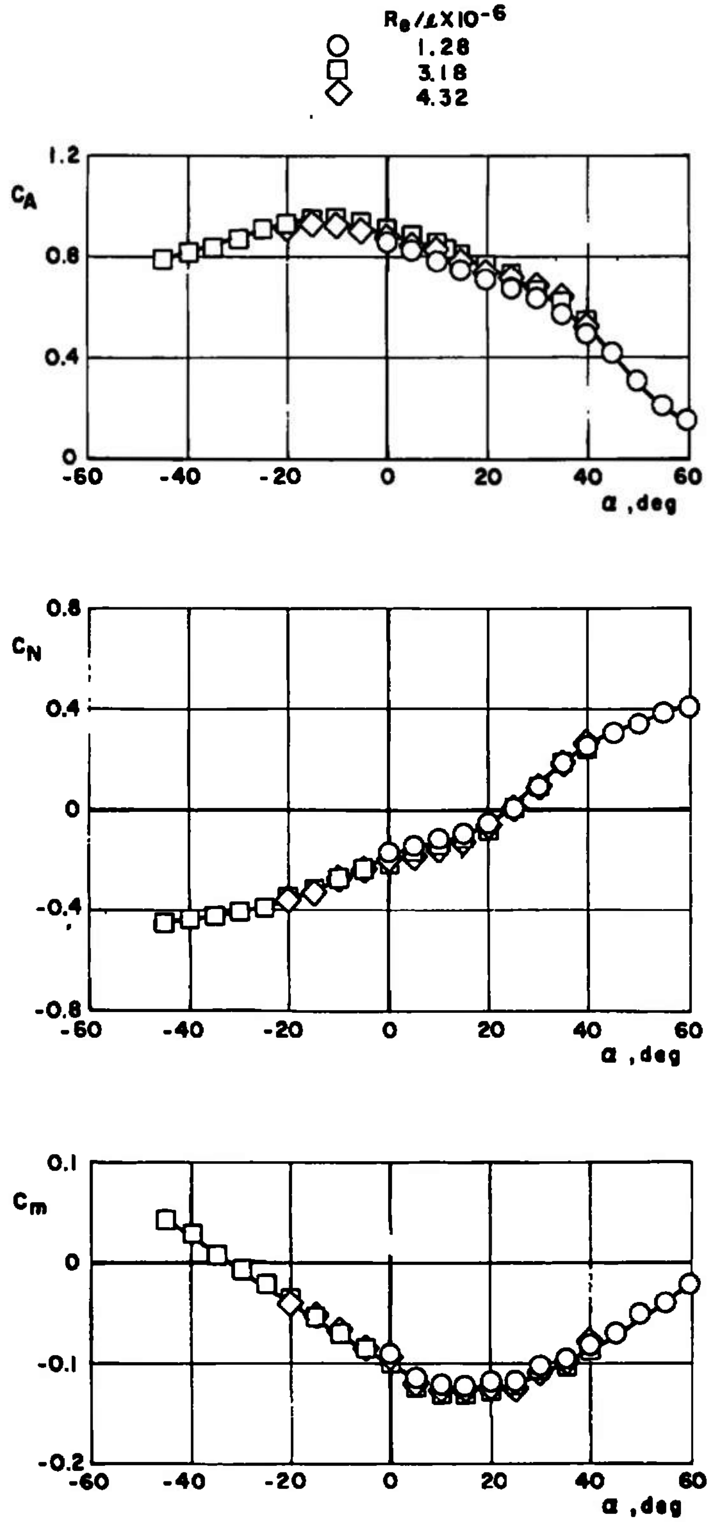


Fig. 4 Model Body Axis Reference System

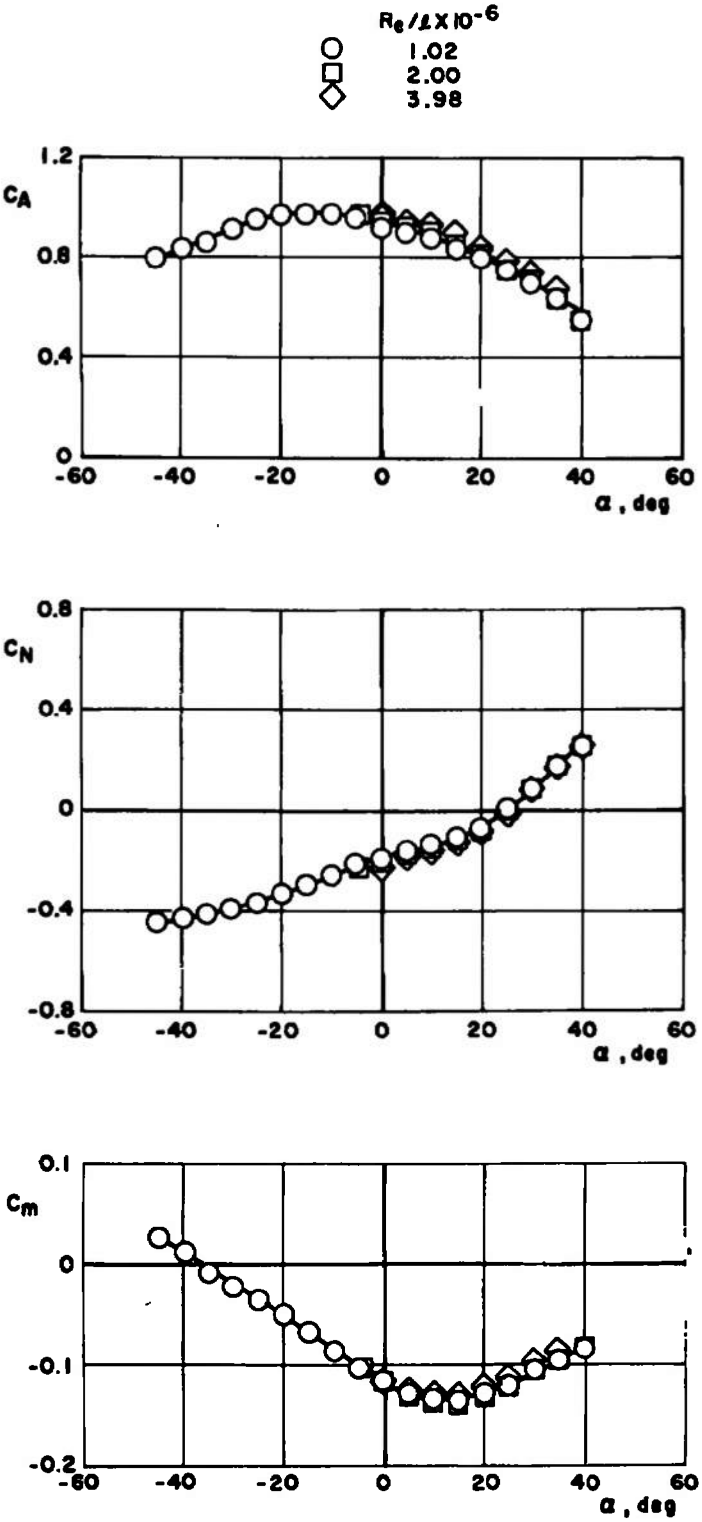


a. $M_\infty = 0.4$

Fig. 5 Effect of Reynolds Number on the Model Aerodynamic Characteristics, ψ = 0 deg



b. $M_\infty = 0.6$
Fig. 5 Continued



c. $M_\infty = 0.8$

Fig. 5 Concluded

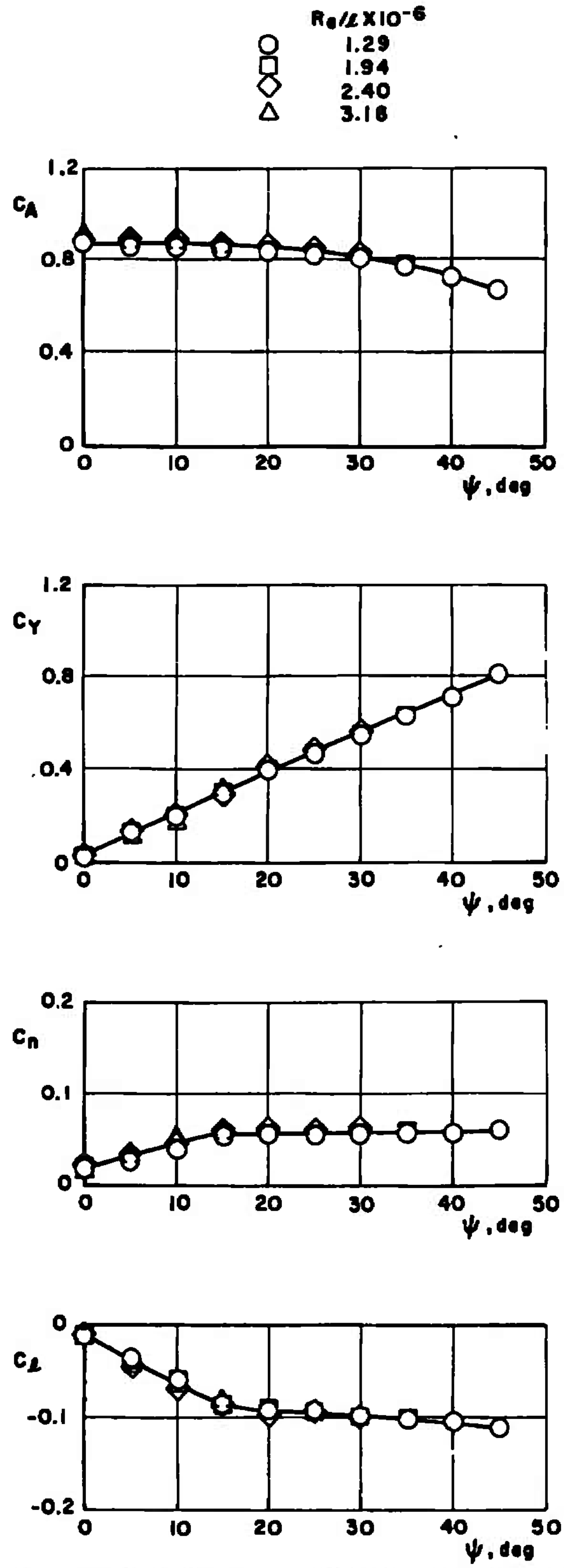
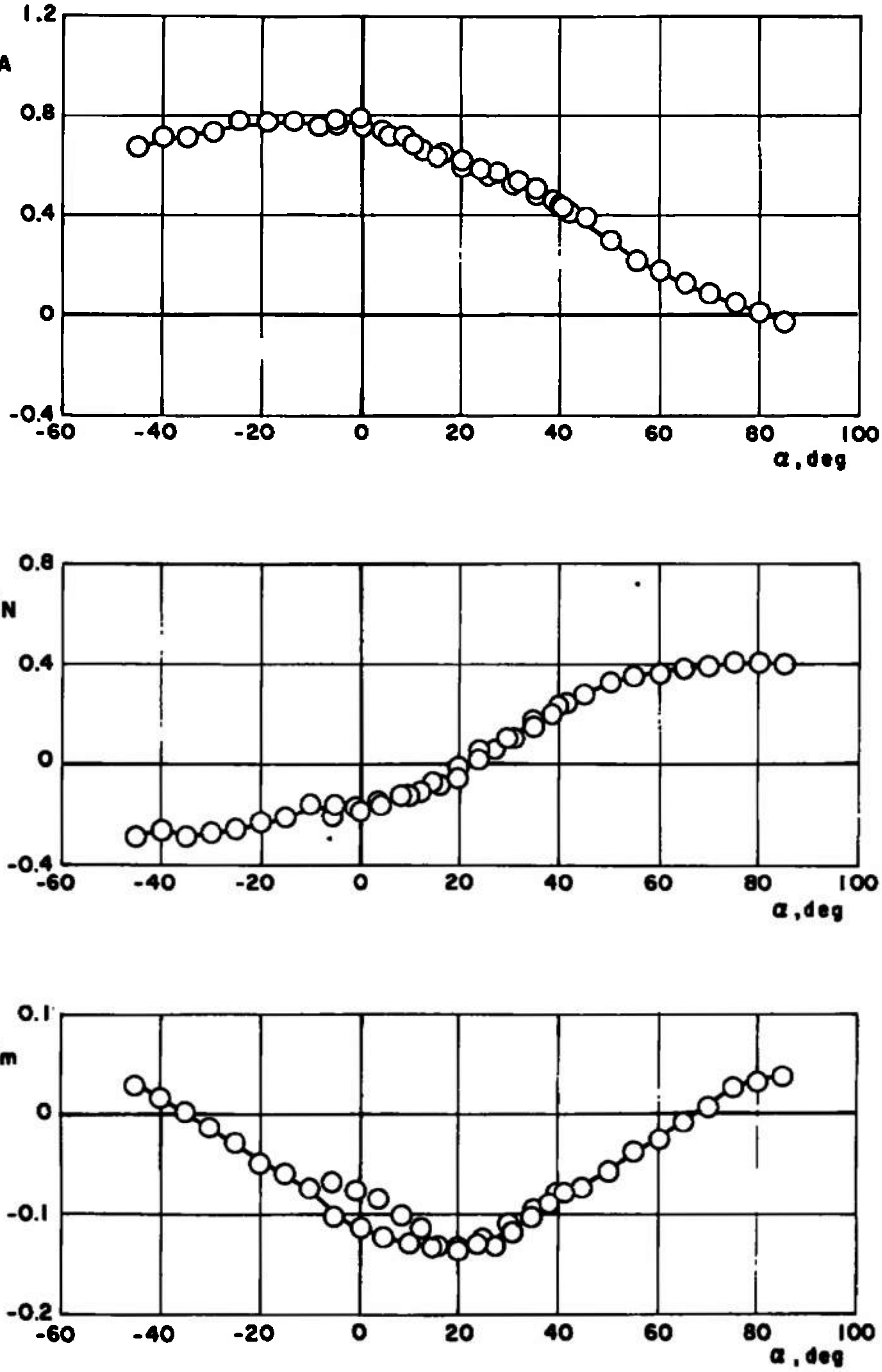
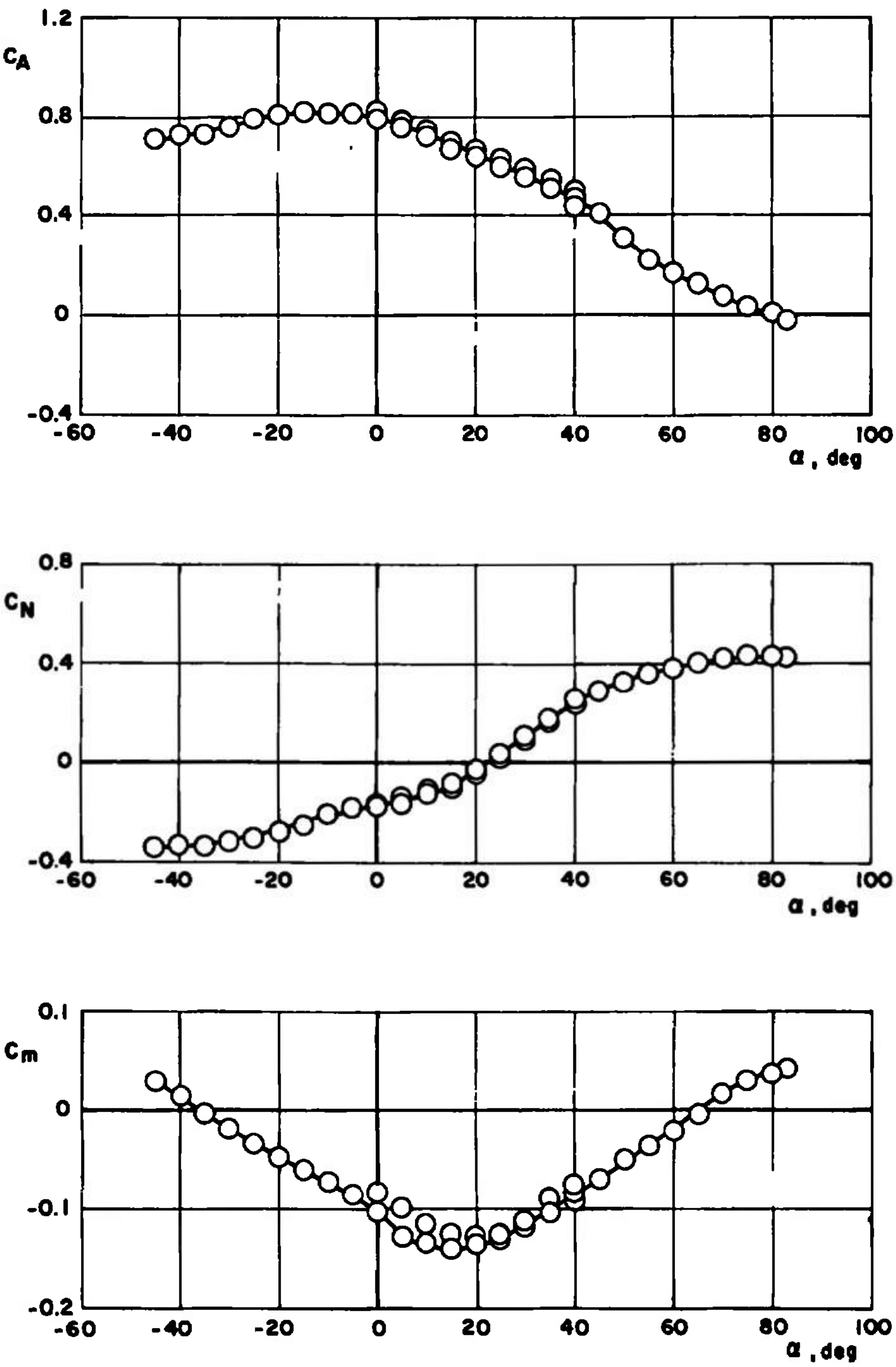


Fig. 6 Effect of Reynolds Number on the Model Aerodynamic Characteristics, $M_\infty = 0.6$, $\alpha = 0$ deg

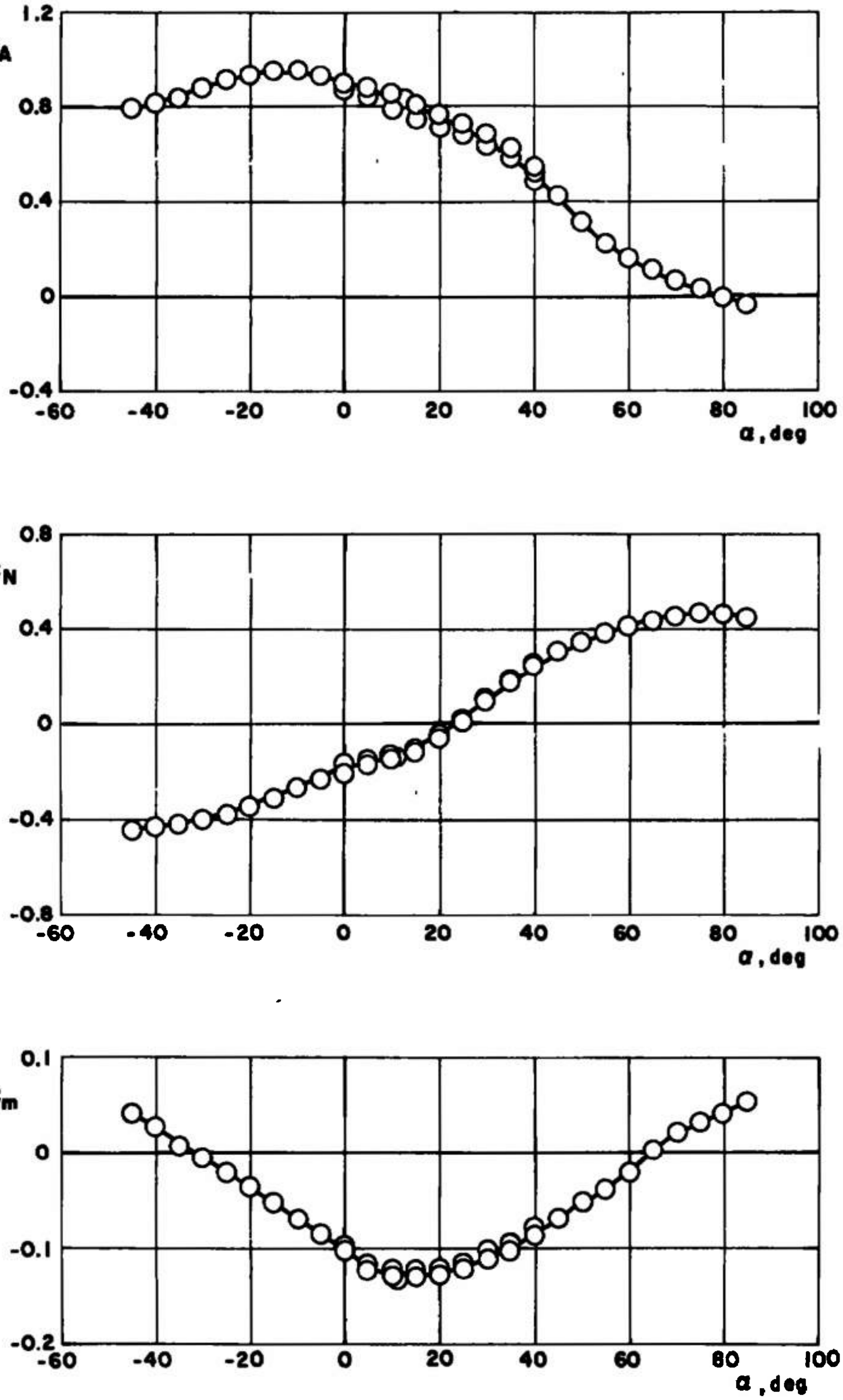


a. $M_\infty = 0.2$

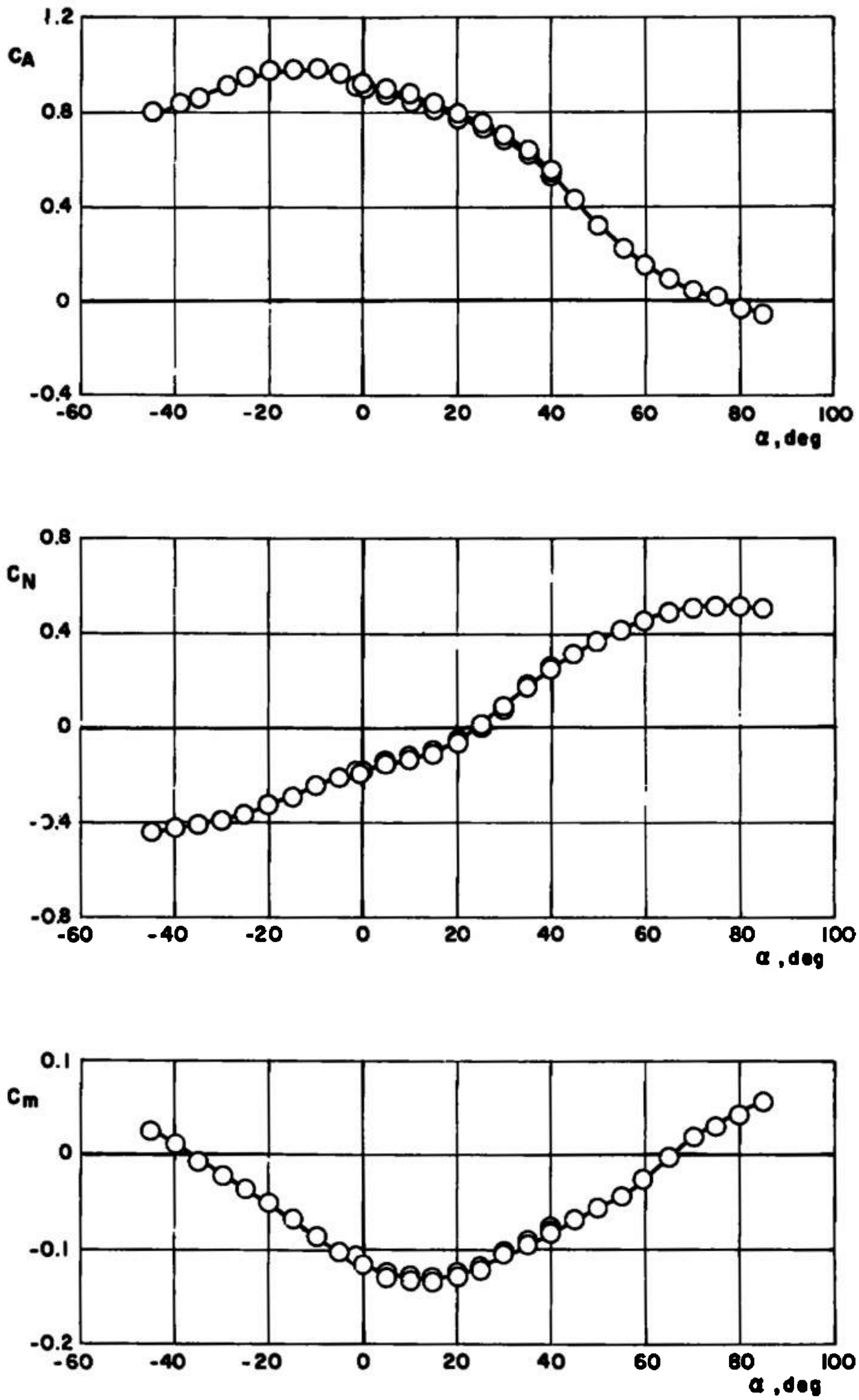
Fig. 7 Variation of Model Force and Moment Coefficients with Angle of Attack, $\psi = 0$ deg



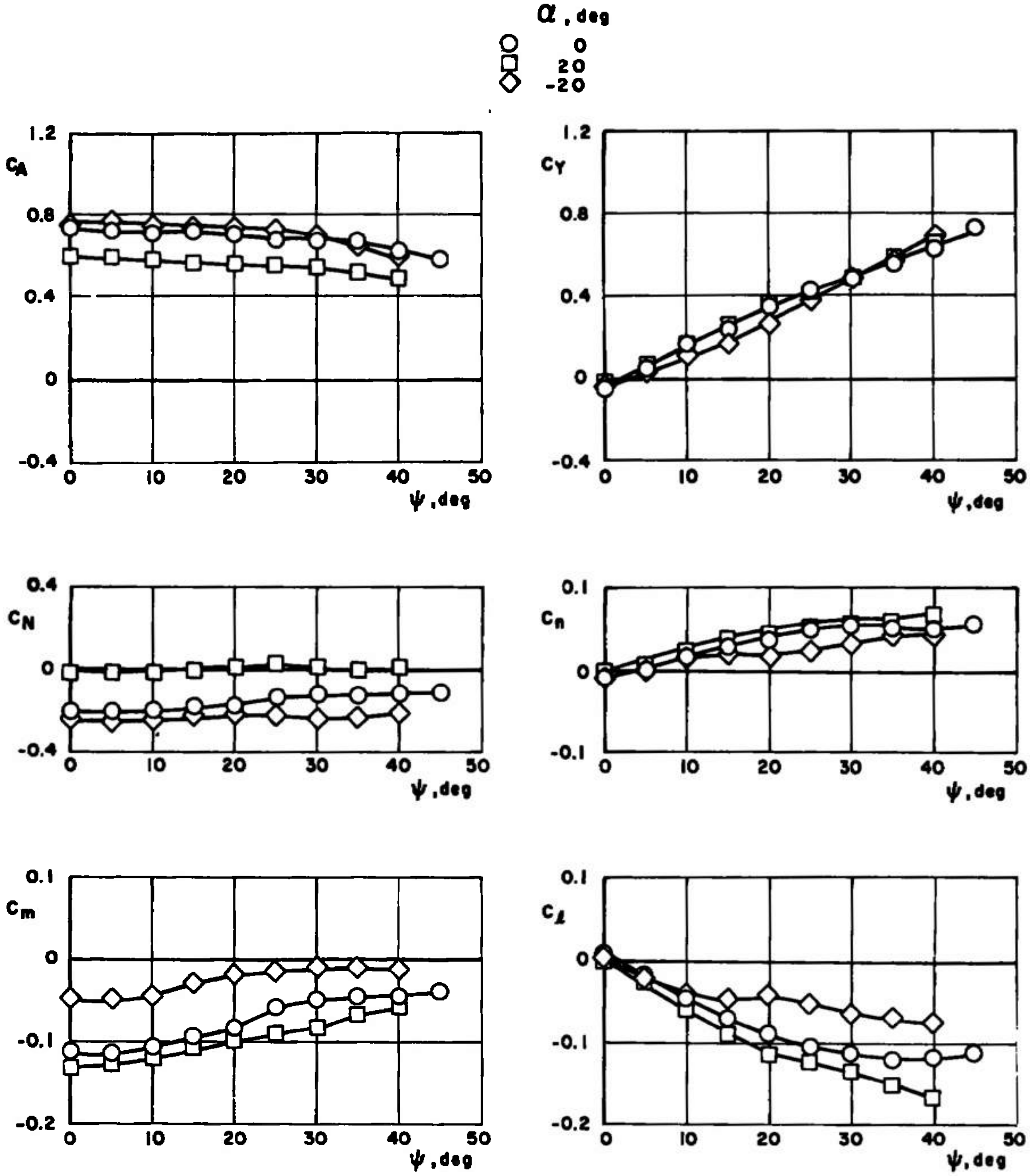
b. $M_\infty = 0.4$
Fig. 7 Continued



c. $M_\infty = 0.6$
Fig. 7 Continued

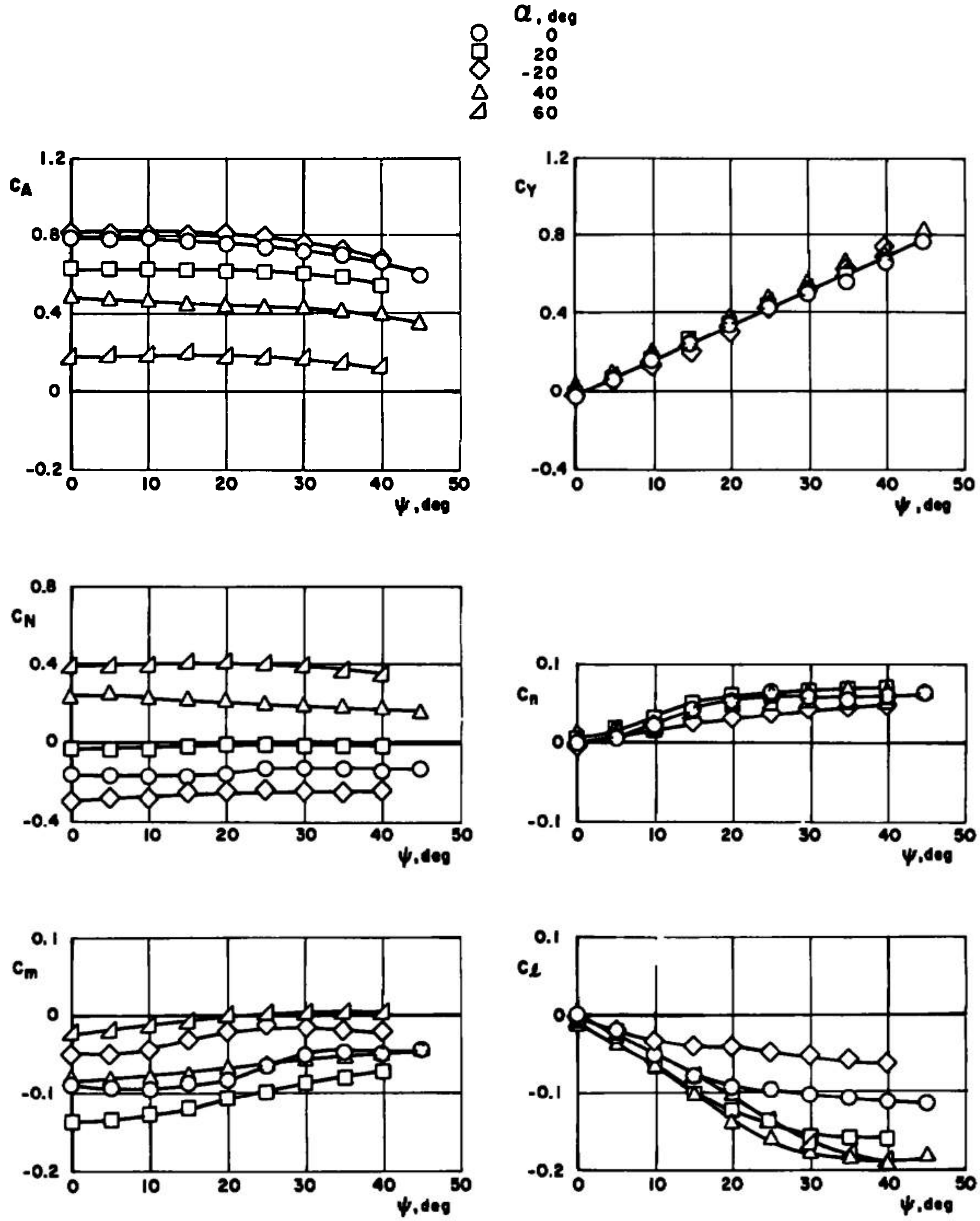


d. $M_\infty = 0.8$
Fig. 7 Concluded



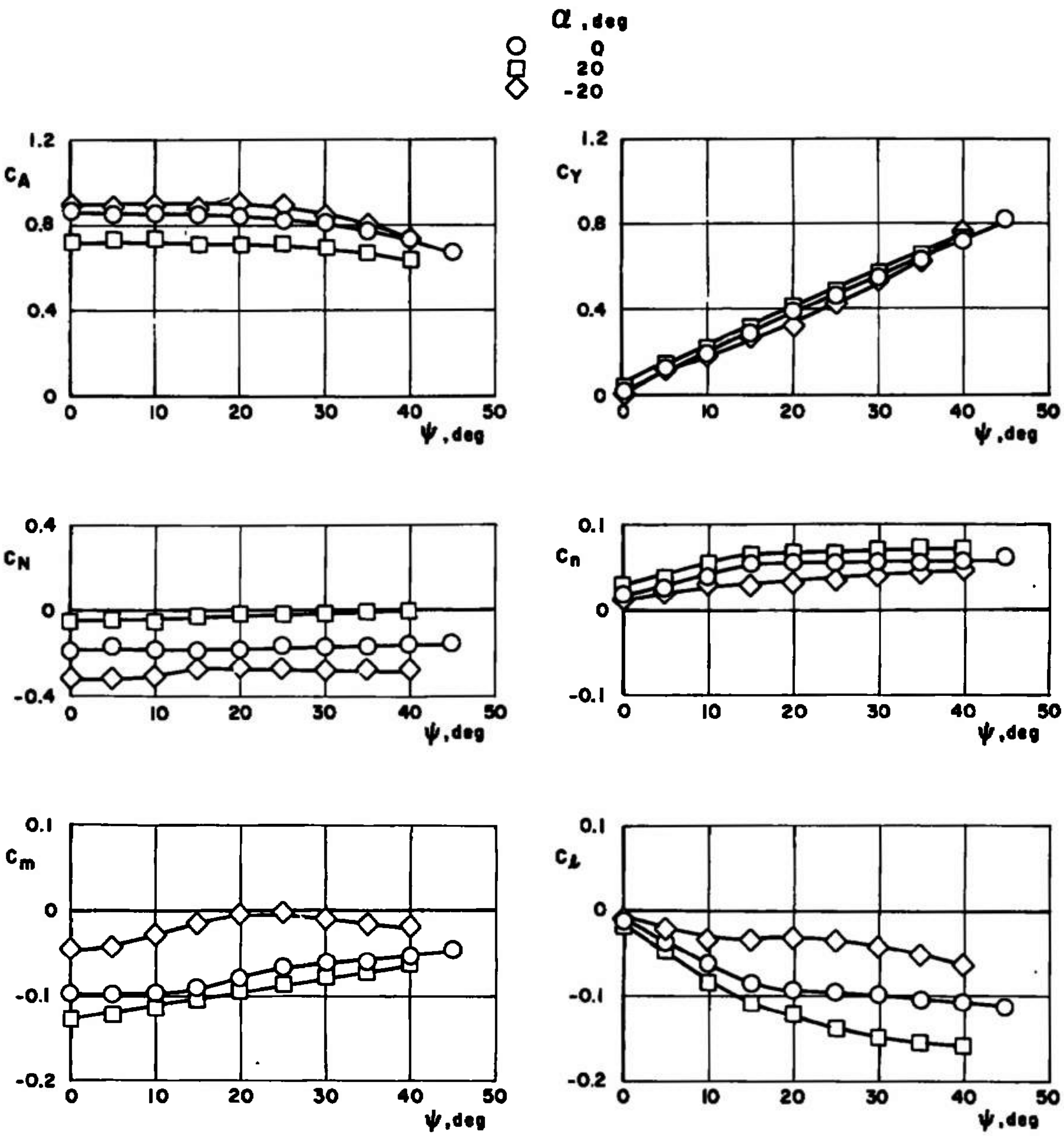
a. $M_\infty = 0.2$

Fig. 8 Variation of Model Force and Moment Coefficients with Angle of Yaw at Constant Angles of Attack

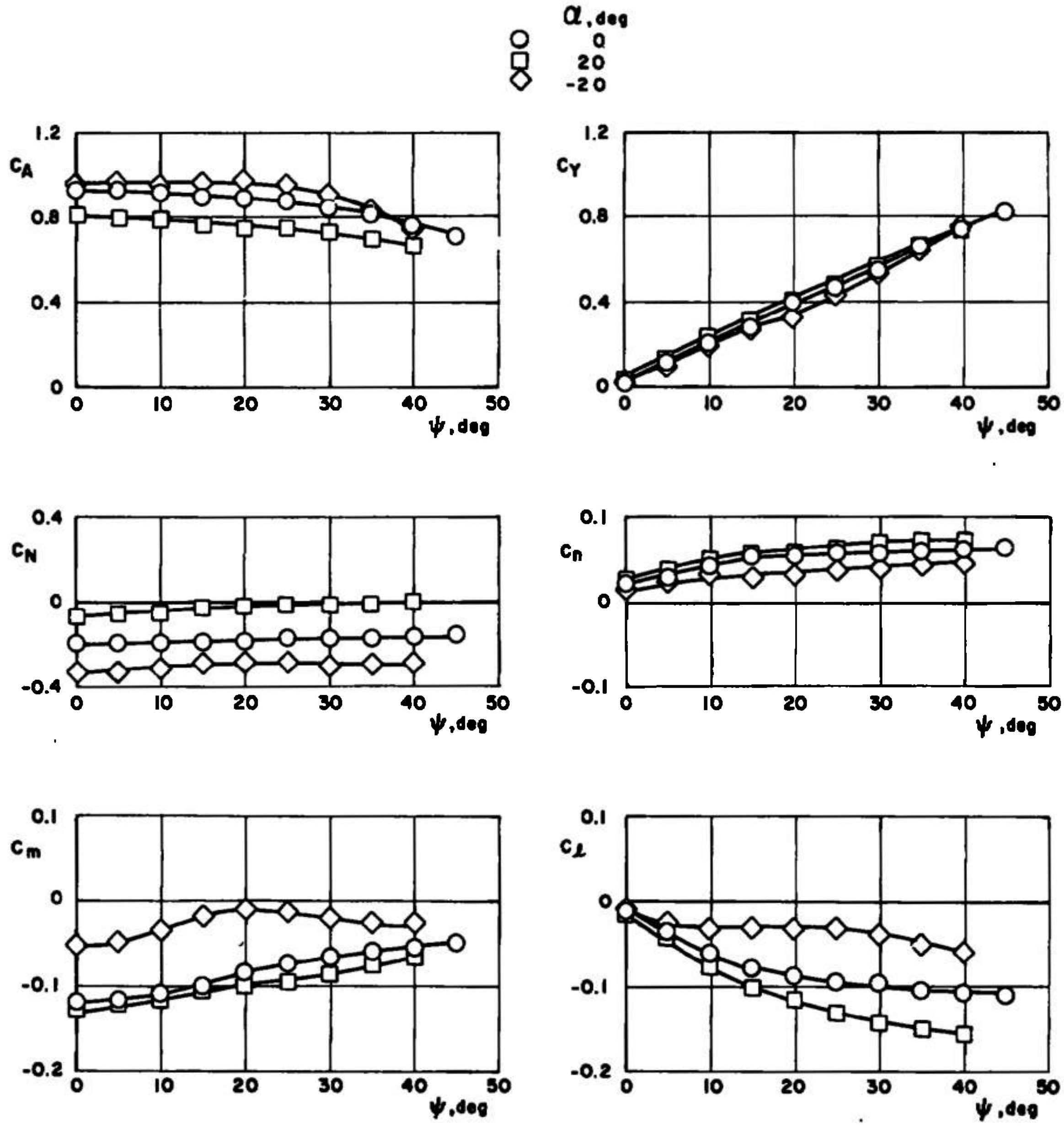


b. $M_\infty = 0.4$

Fig. 8 Continued



c. $M_\infty = 0.6$
Fig. 8 Continued



d. $M_\infty = 0.8$
Fig. 8 Concluded

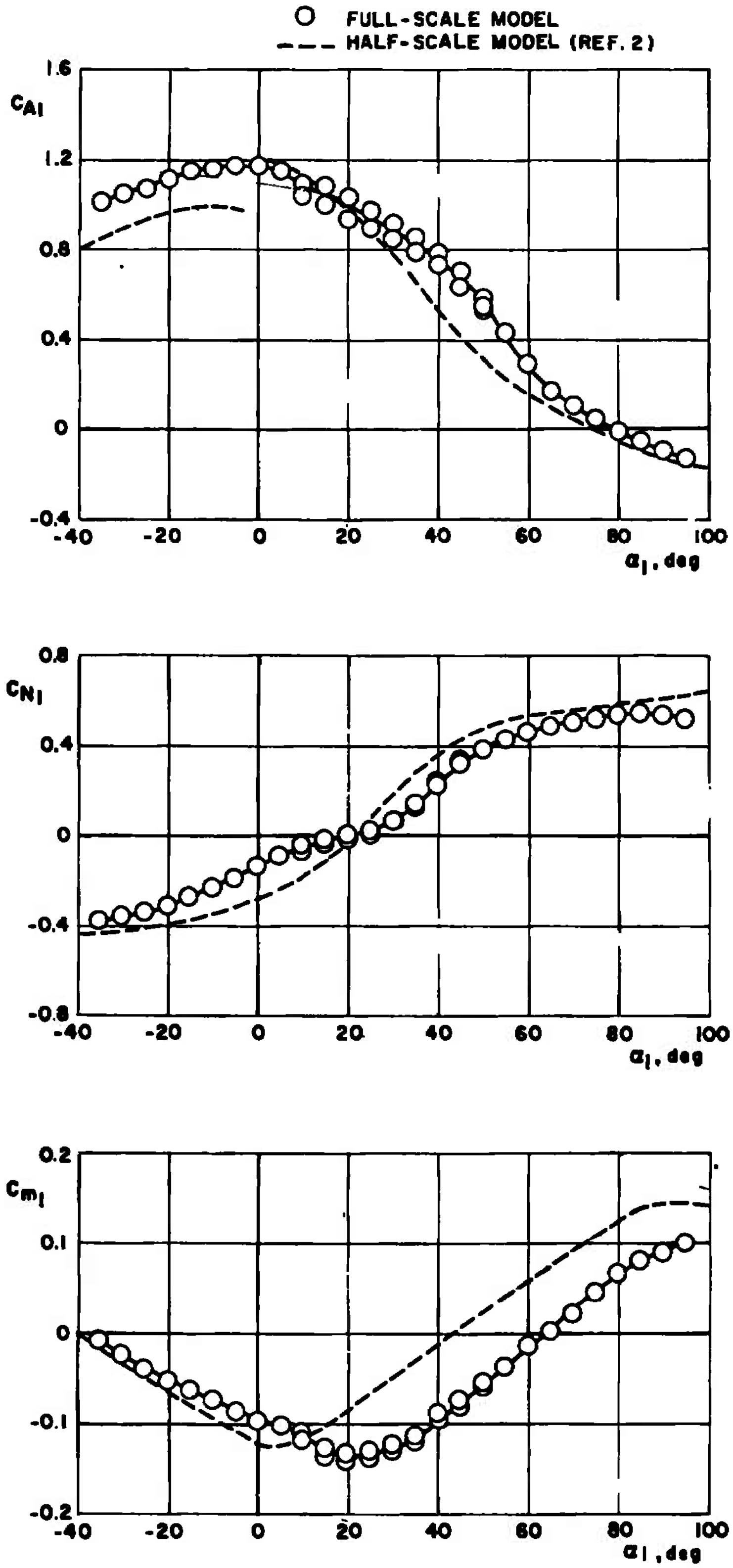


Fig. 9 Data Comparison between Full- and Half-Scale Ejection Seat Models, $M_\infty = 0.6$, $\psi = 0$ deg

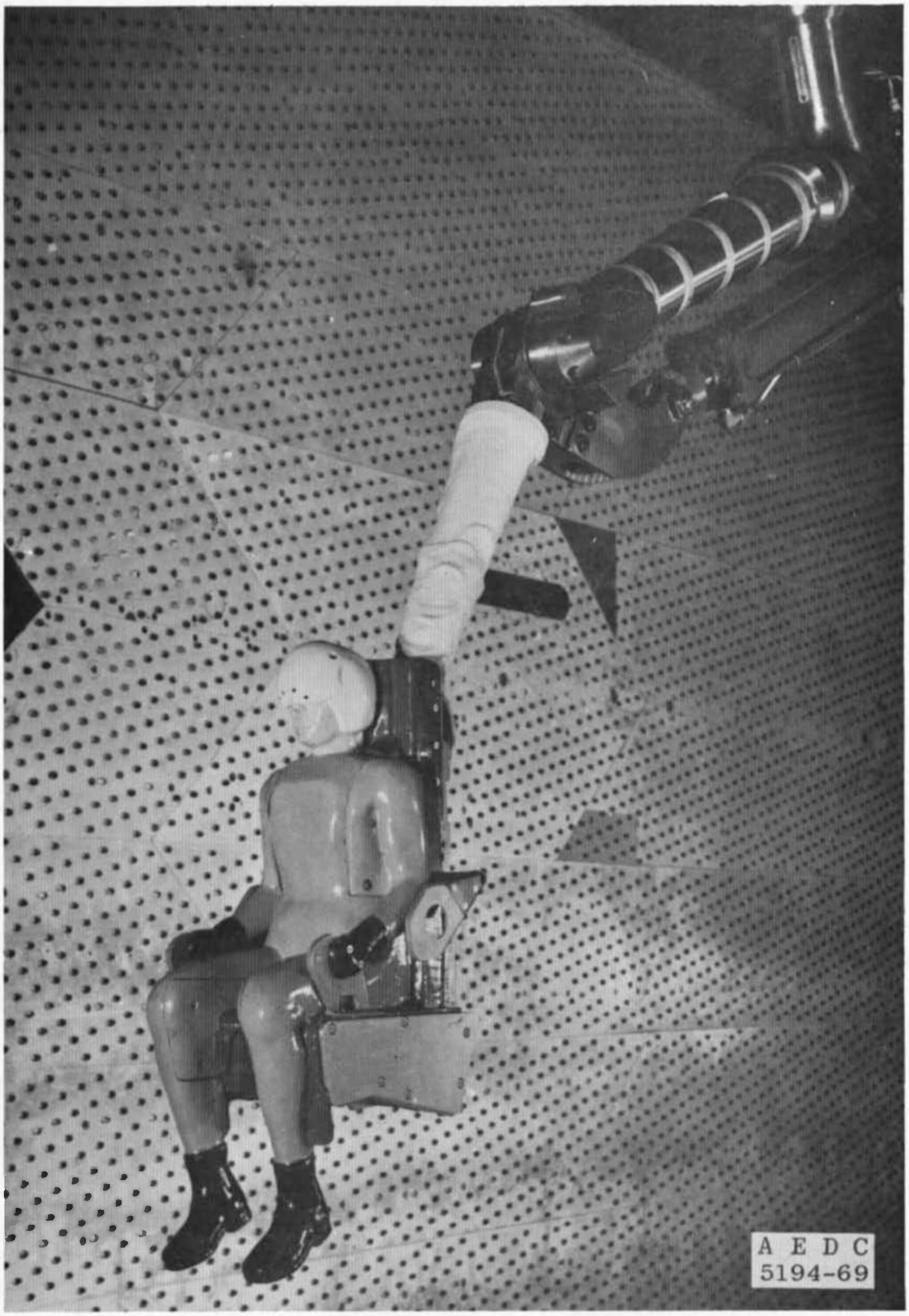


Fig. 10 Half-Scale Model Installation Photograph

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ejection seats						
aerodynamic characteristics						
subsonic flow						
angle of attack						
full-scale models						

AFSC
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